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PARTICULATE SILICONE RUBBER: AN EFFECTIVE, REMOVABLE ENCAPSULAN--ETC(U)

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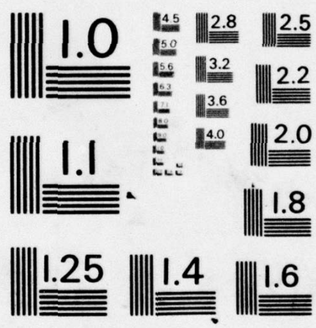
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Embedment	Shock isolation
Encapsulation	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A method of encapsulating electronic circuit board assemblies that enables rapid application and removal of the encapsulant was developed and evaluated. Low-density, inexpensive, foamed silicone rubber particles that are environmentally and electrically stable were used in lieu of conventional hard "potting." The silicone rubber particles can be easily applied by pouring and packing into electronic package voids; they are likewise easily over

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removed from the package (and reusable), should circuit maintenance or rework be necessary.

Vibration tests of typical missile-borne applications indicate that, at resonance, electronic-circuit-board assemblies protected by this method experiences less than 10 percent of the acceleration measured before encapsulation.

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FIGURES

1. INTRODUCTION

Epoxies and foamed polyurethanes are widely used, effective encapsulants for electronic circuits.[1] When molded around circuit-board assemblies and allowed to cure to a rigid state, they offer effective protection in shock and vibration environments by limiting excessive motion of the boards, components, and electrical connection; they also avert many unwanted microphonic effects in the circuit. However, once a subassembly or complete system is "potted," it becomes difficult and costly to make circuit repairs and modifications. To gain access to circuit components, one must tediously burrow into the rigid encapsulant. Even when the encapsulant is removed carefully, inadvertent component damage sometimes occurs.

2. AN ALTERNATIVE ENCAPSULATION CONCEPT

It has been found that if a loose fill of silicone-rubber particles is used as an encapsulation medium, the service and repair problems associated with rigid potting compounds are virtually eliminated. Discrete pellets or flakes of silicone rubber can be "poured" into available cavities surrounding circuit-board assemblies. The package is then sealed and ready to be used. Also noteworthy with this type of particulate encapsulant, there is no need for "potting" molds; nor are there lengthy cure cycles at elevated temperatures. Most importantly, if rework is necessary, the encapsulant can be easily dumped out or vacuumed from the electronic package.

The particulate encapsulants were reduced by these laboratories from bulk pieces of foamed silicone rubber. Two distinct particle shapes were derived, depending on how they were cut from the parent material:

a. Pellets were snipped from long lengths of 3/16-in.-diam extruded strands of silicone foam rubber (fig. 1, 2).

b. Flakes were formed when chunks of silicone foam rubber were fed through a household meat grinder, giving the material the appearance of "rubber sawdust" (fig. 2).

The physical properties of silicone foam rubber make it ideal for use in electronic packages. Several silicone compounds that were evaluated were found suitable because they have all of the following essential properties:

a. Chemical inertness: the compound must not decompose or initiate corrosion and must have long shelf life.

[1] *Charles A. Harper, ed., Handbook of Electronic Packaging, McGraw-Hill Book Co., New York (1969).*

(a)

(b)

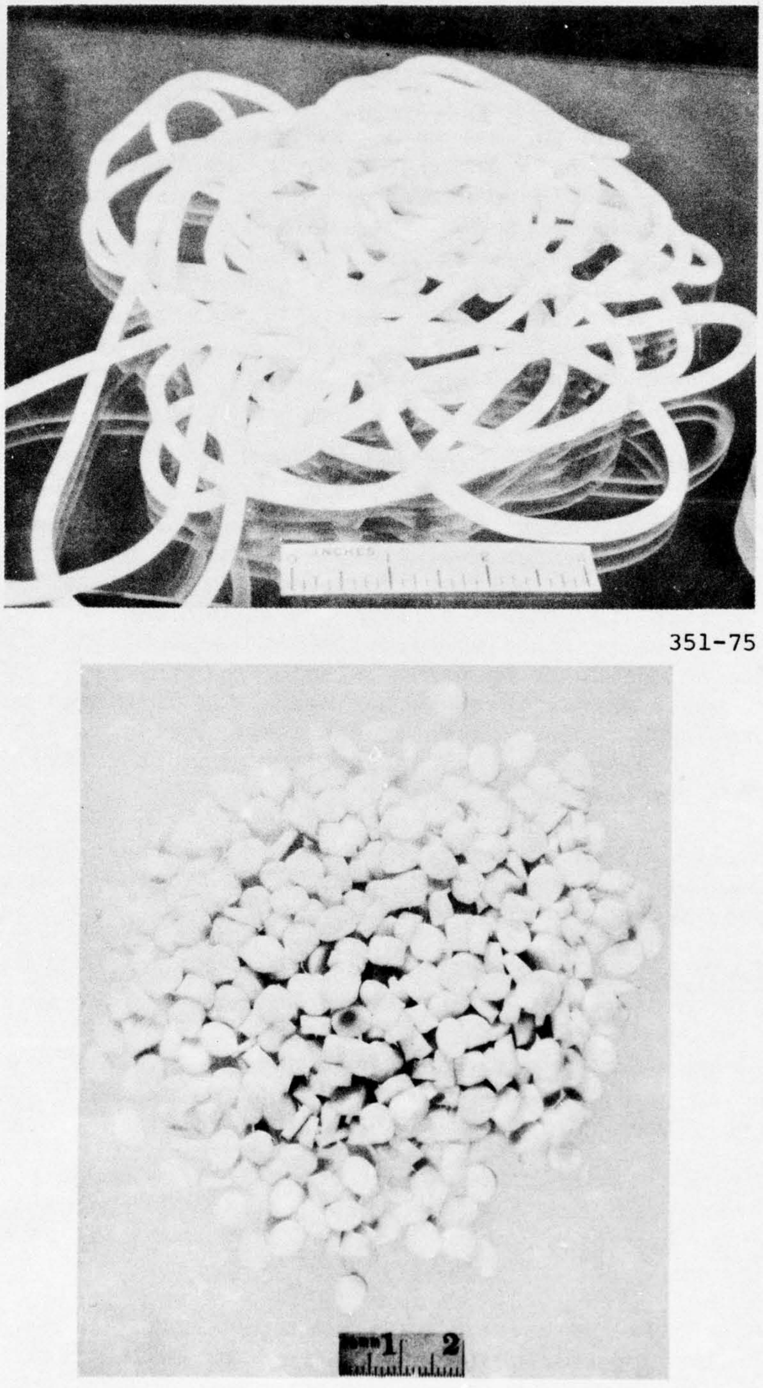

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Figure 1. Pellet formation; (a) foam "spaghetti," (b) snipped pellets.

(a) (b)

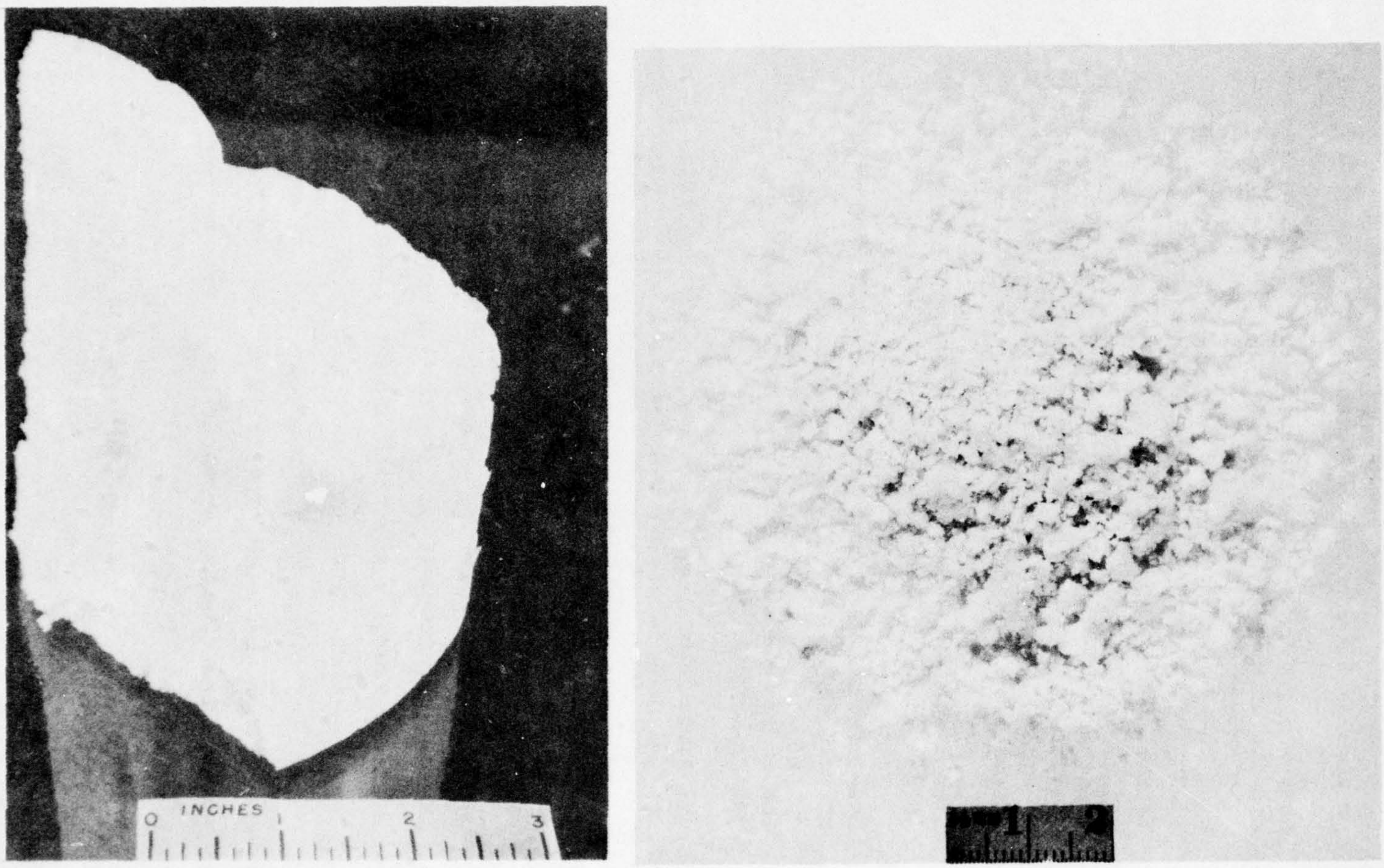

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Figure 2. Flake formation; (a) bulk foam rubber, (b) ground flakes ("rubber sawdust").

b. Temperature insensitivity: the compound must maintain properties at high and low temperature extremes.

c. Removability: particle cohesion and adhesion to the circuitry and container should be negligible.

d. Good vibration damper: the compound must be able to mitigate the motion of the parts over a wide range of vibration frequencies and amplitudes.

e. Electrical inertness: the compound must not affect the circuit operation. This essentially requires high dielectric strength, a small dielectric constant, high resistivity, and a low dissipation factor.

f. Light weight: the encapsulant should not significantly increase the total weight of the package.

g. Low moisture absorptivity: the encapsulant should not absorb or hold moisture.

h. Low cost: the cost should be small relative to the cost of the entire system.

A material that was found to possess these properties is a silicone foam rubber (polymer) resulting from the following chemical reaction:

$$-\underset{|}{\overset{|}{\mathrm{Si}}}-\ \mathrm{H} + \mathrm{HO}\ -\underset{|}{\overset{|}{\mathrm{Si}}}- \xrightarrow{\text{Tin Octoate}} -\underset{|}{\overset{|}{\mathrm{Si}}}-\ \mathrm{O}\ -\underset{|}{\overset{|}{\mathrm{Si}}}- + \mathrm{H_2}\uparrow$$

A prepolymer of the material consisting of a silane ($-\underset{|}{\overset{|}{\mathrm{Si}}}-\mathrm{H}$) plus a silanol ($\mathrm{HO}-\underset{|}{\overset{|}{\mathrm{Si}}}-$) structure react in the presence of the catalyst, tin octoate, as noted above; i.e., the silanic hydrogen and the hydroxyl group in the polymer react in the presence of the catalyst to form a siloxane chain ($-\underset{|}{\overset{|}{\mathrm{Si}}}-\mathrm{O}-\underset{|}{\overset{|}{\mathrm{Si}}}-$) with hydrogen ($H_2$) released. The hydrogen serves as a blowing agent and is instrumental in foaming the silicone polymer. A weak base such as amine is included to neutralize any free acid that may be present.

Typical, commercially available products that have been found to possess the aforementioned essential properties are Dow Corning RTV90-224, Emerson and Cumming Eccofoam SIL, and a silicone "spaghetti" made by Moldit Corporation. Manufacturers' data provided some of this information. Thermogravimetric and corrosion tests verified chemical inertness. A loose fill of the particles of each weighed approximately the same, 0.38 to 0.40 g/cc. The ingredients to make bulk quantities of the foam rubber cost \$5 to \$13/lb at the time of this report. The individual manufacturers can furnish other material specifications.

3. MEASUREMENT OF DAMPING EFFECTIVENESS

Sinusoidal vibration tests of electronic circuit-board assemblies were used to determine the effectiveness of foamed silicone-rubber particle encapsulation. A printed circuit-board assembly (2.09 × 4.06 in.) was mounted on standoffs in an aluminum fixture (fig. 3, 4). This fixture was intentionally designed to provide a large unsupported span for the printed-circuit board. Thus, the configuration ensured an exaggerated vibration response of the assembly. This

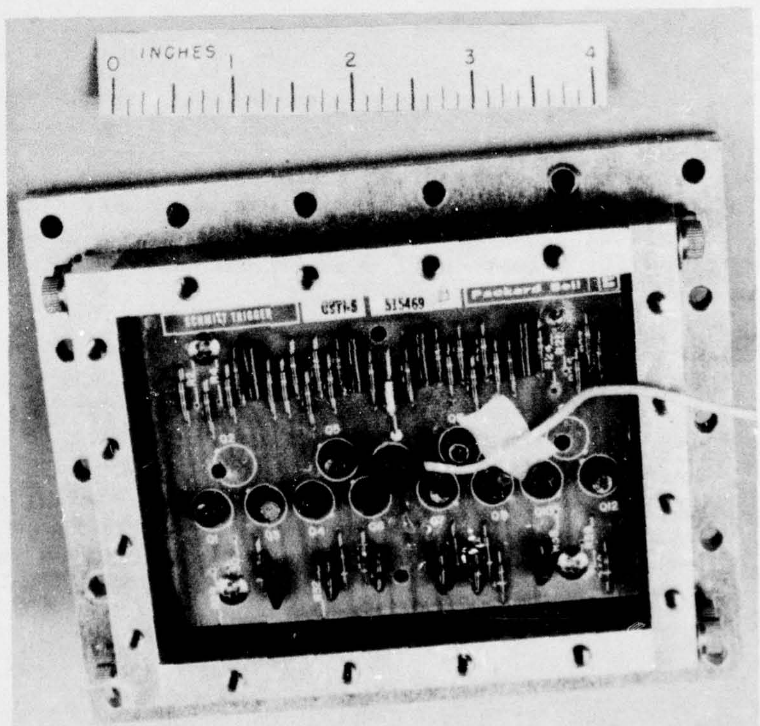

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Figure. 3. Experimental package, unencapsulated.

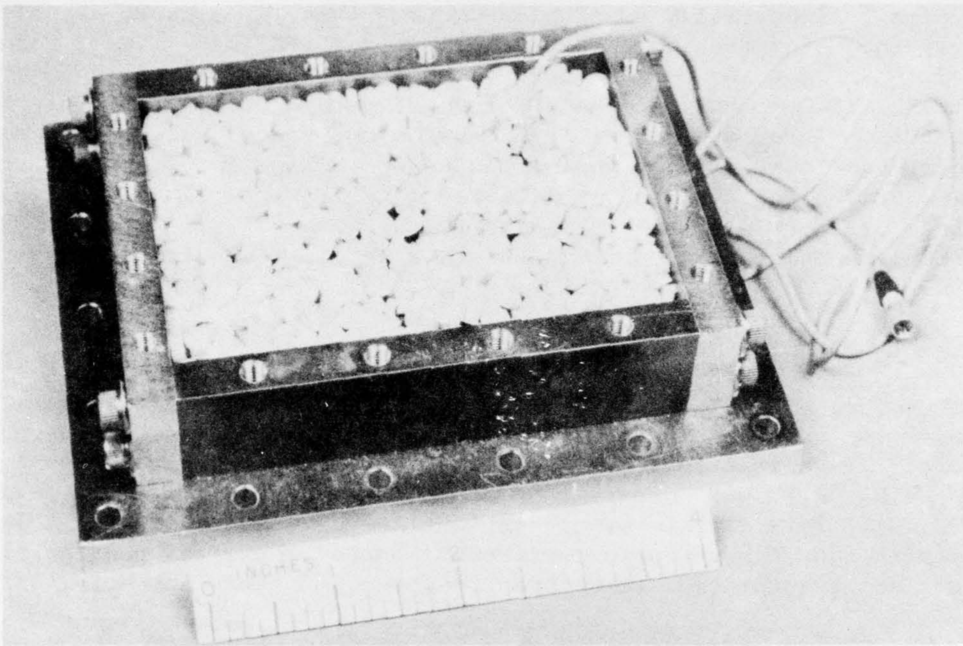

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Figure 4. Experimental package, *encapsulated (cover removed)*.

assembly was subjected to sinusoidal vibration excitation of 2-g peak in the range of 10 to 2000 Hz. A miniature accelerometer, attached at the center of the circuit-board assembly, sensed the specimen's response. (Further details of the test configuration and instrumentation are given in app A.)

Test results are summarized in figures 5 to 7. The response is expressed as amplification factor or the ratio of the output to the input acceleration. A comparison of the results in figure 5 with those in figures 6 and 7 shows the beneficial damping effect at resonance of the foamed silicone-rubber particle encapsulant. The results show also that the four variations of the encapsulant were equally effective in vibration damping. Further noteworthy, a 1/3 overfill of encapsulant particles yields only a minor improvement in the vibration damping. The encapsulant materials were reused several times with no change in performance.

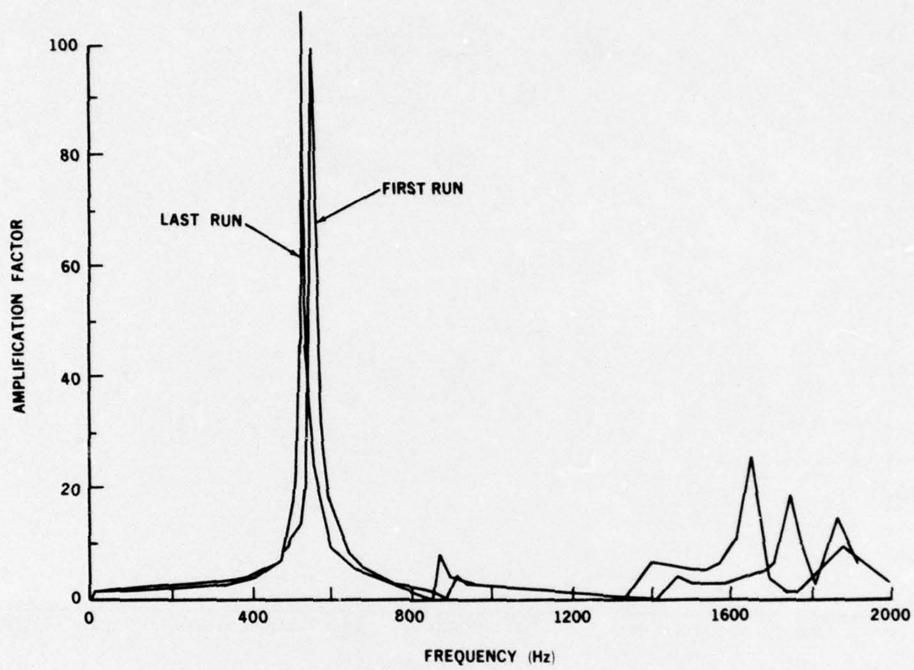

Figure 5. Response to 2-g sinusoidal vibration, amplification versus frequency, unencapsulated experimental package.

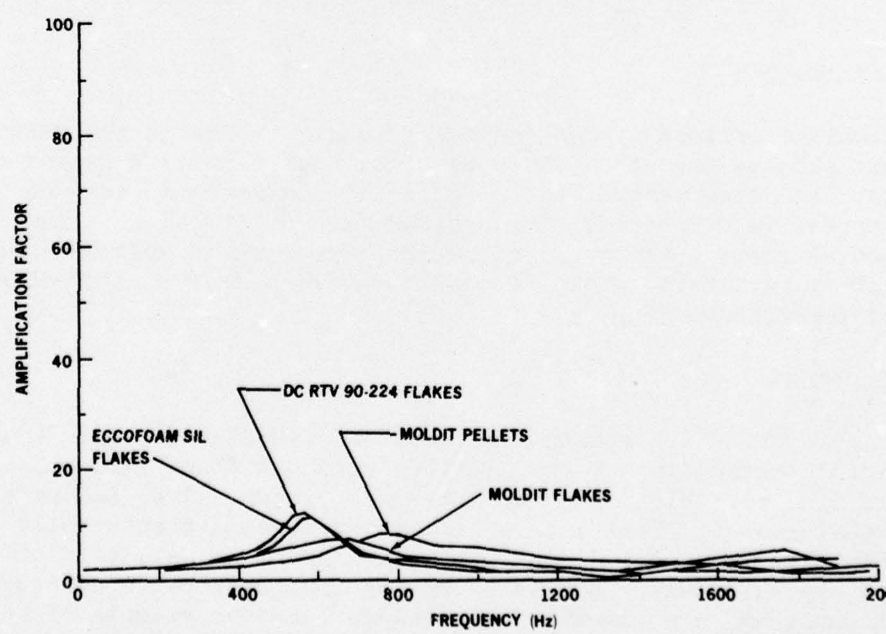

Figure 6. Response to 2-g sinusoidal vibration, amplification versus frequency, experimental package encapsulated with four different compounds.

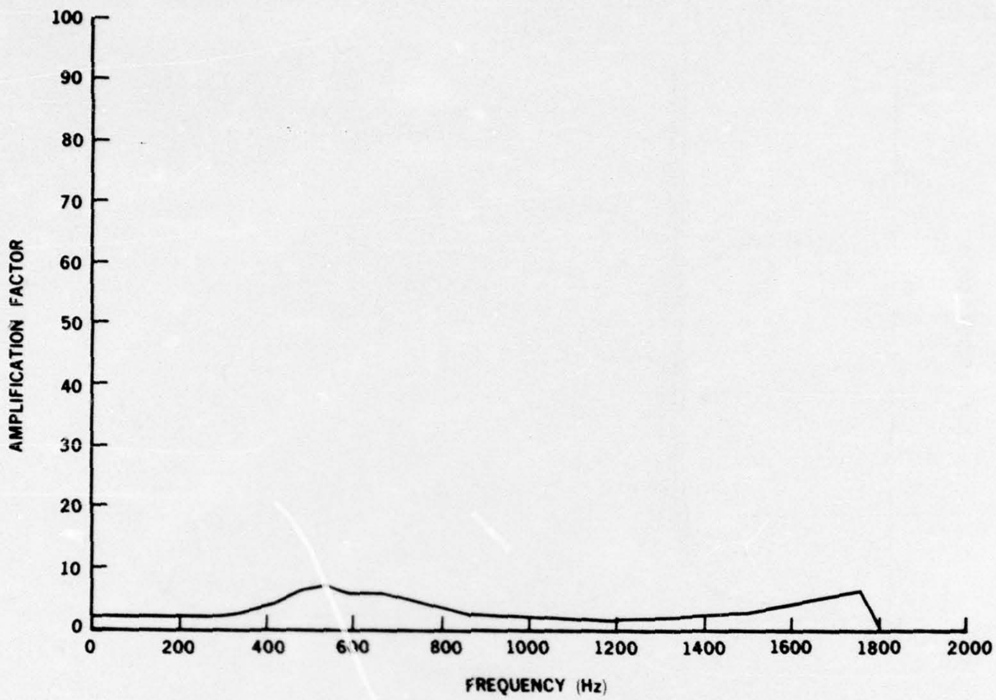

Figure 7. Response to 2-g sinusoidal vibration, amplification versus frequency, experimental package encapsulated with 1/3 overfill of DC RTV 90-224.

4. AN APPLICATION

Particulate silicon rubber encapsulants are in use in the XM818 fuze electronic package for the SAM-D missile. For a small fraction of the fuze cost and fuze weight, the electronic components are cushioned against excessive vibration. The package was subjected to a battery of environmental tests without a vibration or shock-induced malfunction. Results of experiments with sample hardware had given indications of this good functioning (app B).

5. CONCLUSIONS

The encapsulants described here offer several advantages over the conventional potting practice. Silicone-rubber flakes and pellets are removable and reusable, lightweight, and inexpensive and offer high damping performance. They are environmentally and electrically inert. They should be considered in packaging problems similar to those described here, namely, in missile fuzing applications. However, for applications that are considerably different (for example, tube-fired munitions), the evaluations done here should be extended.

APPENDIX A.--AN EXPERIMENT FOR EVALUATING THE VIBRATION DAMPING ABILITY OF ENCAPSULANTS

Figure A-1 details the test configuration and instrumentation for for the particulate silicone rubber encapsulant.

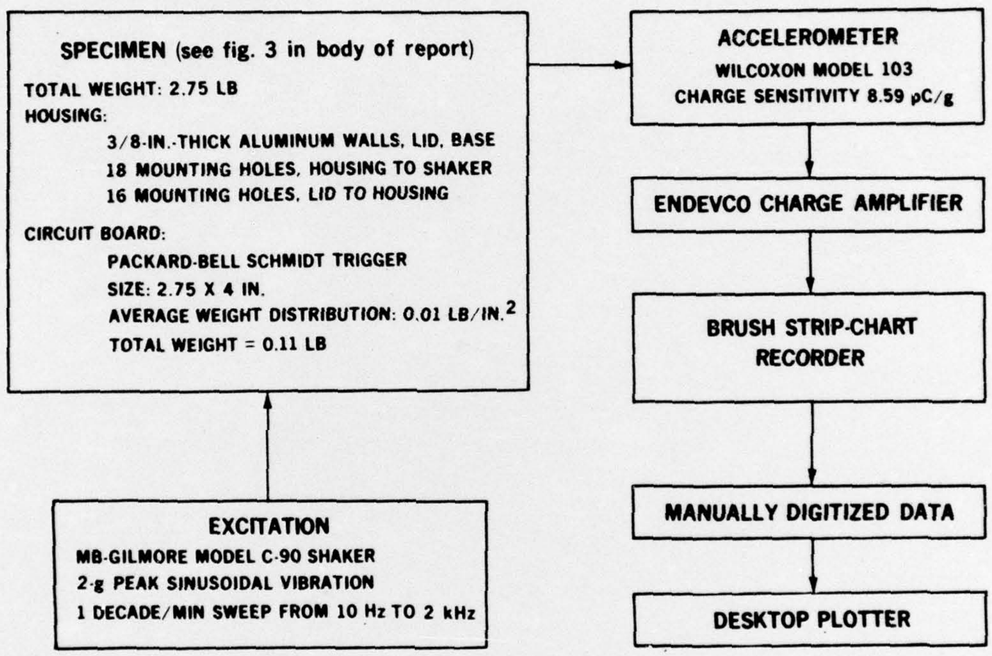

Figure A-1. Test configuration and instrumentation.

APPENDIX B.--EVALUATING ENCAPSULANTS IN AN XM818 FUZE SUBASSEMBLY

Prior to the acceptance of silicone-rubber flakes as an encapsulant for the XM818 Electronic Assembly, tests were conducted to qualify this material and match it against the potting-in-place method. One electronic module was chosen as representative of the other fuze subassemblies (fig. B-1). In this package, five similar circuit boards set in a housing of as many cells. These boards are held at the lateral edges by Birtcher tracks (spring-loaded clips).

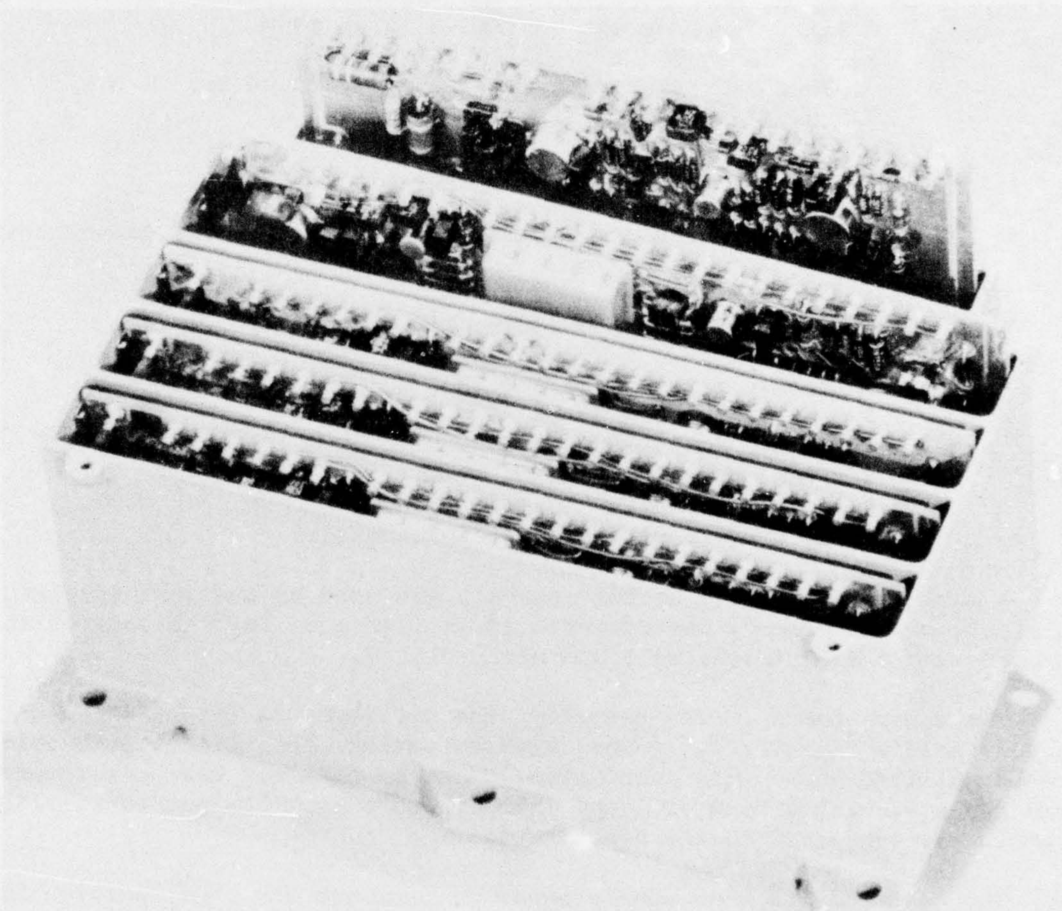

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Figure B-1. Circuit boards in the cells of a representative XM818 fuze module.

APPENDIX B

A test series was programmed to simulate the transportation and flight environments of the fuze. The XM818 fuze is required to survive or operate in the following vibration environments:

a. Transportation (sinusoidal) vibration (nonoperating circuits)

Sweep up

0.3-in. displacement amplitude, 5 to 13 Hz
2.5 g, 13 to 38 Hz
0.036-in. displacement amplitude, 38 to 44 Hz
3.5 g, 44 to 500 Hz

Sweep up and down in 15-min total.
Repeat four times.
Input perpenticular to the plane of the printed-circuit board.

b. Flight (random) vibration (operating circuits)

6-dB/octave rise, 50 to 100 Hz
0.3 g /Hz, 100 to 2000 Hz
6-dB/octave fall, 2000 to 3000 Hz
8.8 g RMS overall
3.4-min exposure time
Monitor circuit performance continuously.

A mock-up of one cell of the assembly was used as the test specimen. A single circuit board, instrumented as in figure 3 in the body of the report, was placed in the cell and encapsulated.

Two encapsulants were tested. The specimen was first filled with ground Moldit "spaghetti." The transportation and flight vibration tests outlined above were conducted. The encapsulant was then removed and replaced with a foam silicone rubber potting. The potted-in-place sample was subjected to the same tests.

The test results show nearly equal performance for the particulate and potted encapsulants. The acceleration frequency response plots are nearly identical for transportation vibration (fig. B-2). The circuits performed within design limits before, during, and after the random vibration.

The conclusion drawn from this test sequence is that silicone rubber in particulate form is the equal of potting in place as a vibration damper. Because the discrete encapsulant has other advantages as outlined in the body of the report, it was adopted for use throughout

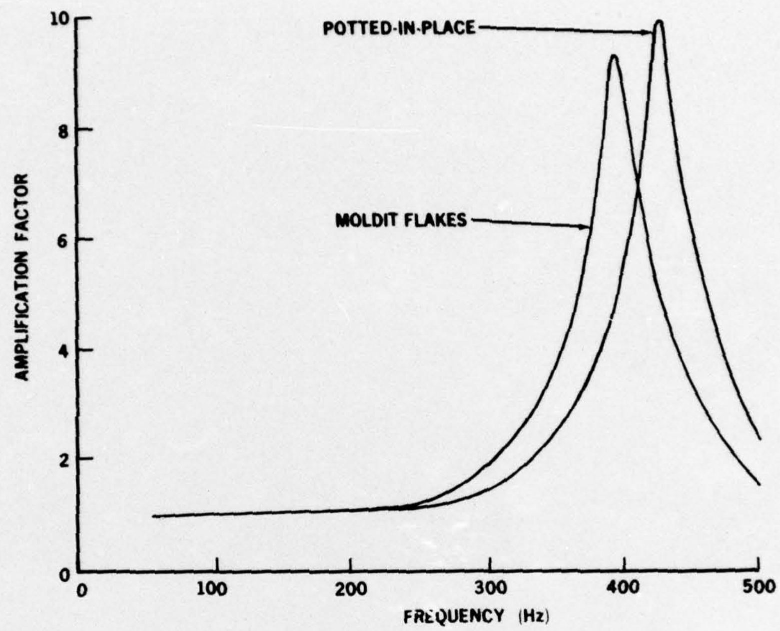

Figure B-2. Response to transportation vibration, amplification versus frequency, circuit board encapsulated two ways.

the XM818 Electronic Assembly (fig. B-3). The encapsulant is poured into every available cavity (fig. B-4) and accounts for slightly more than 1 lb of the 15-lb package.

APPENDIX B

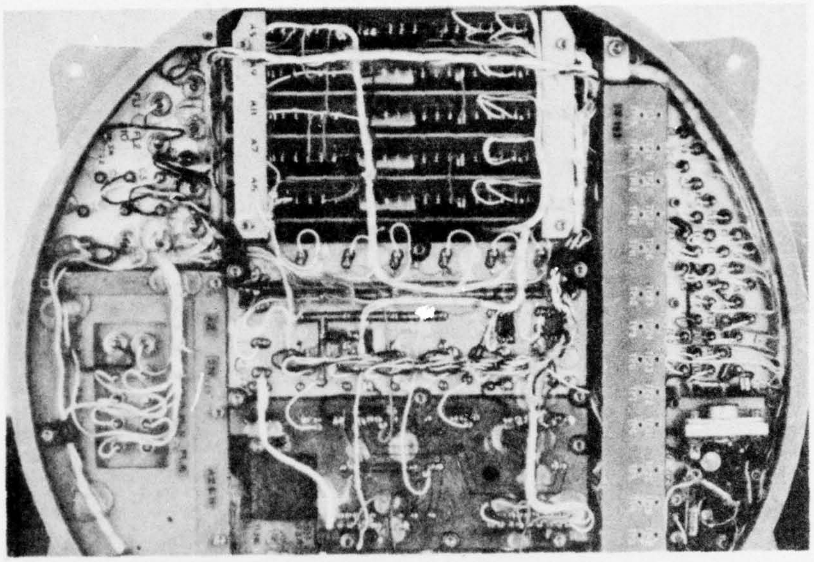

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Figure B-3. The XM818 electronic assembly, before encapsulation.

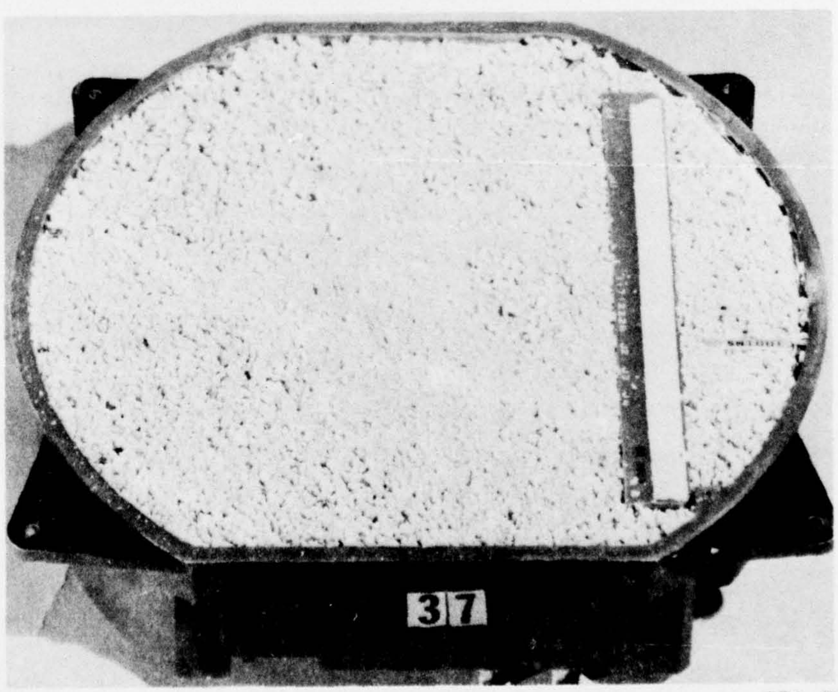

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Figure B-4. The XM818 electronic assembly, opened to expose encapsulant.

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